

June 30, 1931.

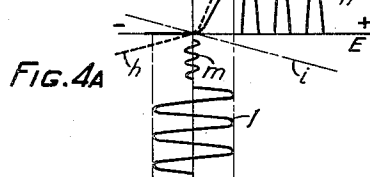
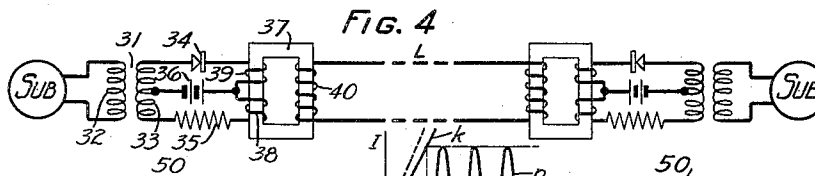
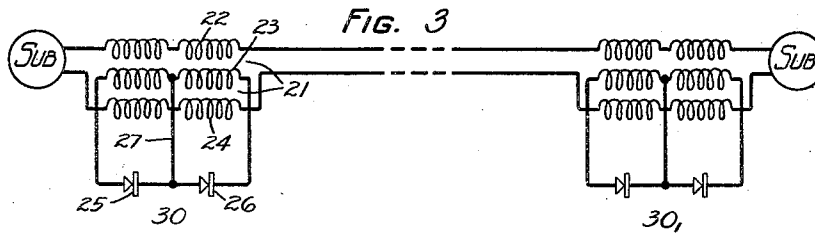
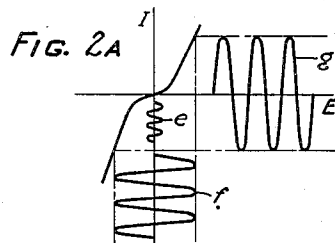
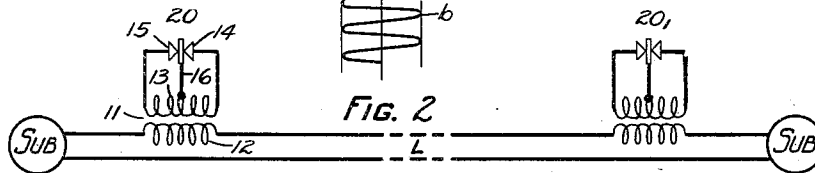
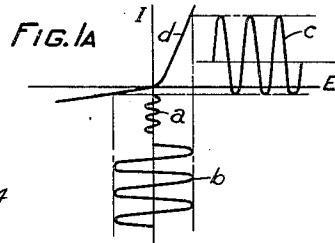
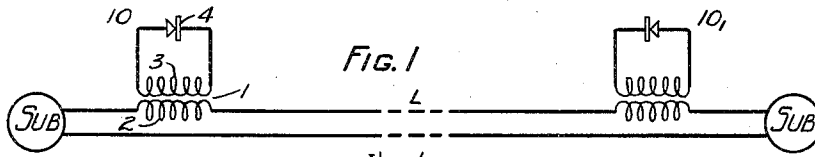
E. PETERSON

1,811,963

APPARATUS FOR REDUCING CROSSTALK CURRENTS

Filed June 20, 1928

3 Sheets-Sheet 1



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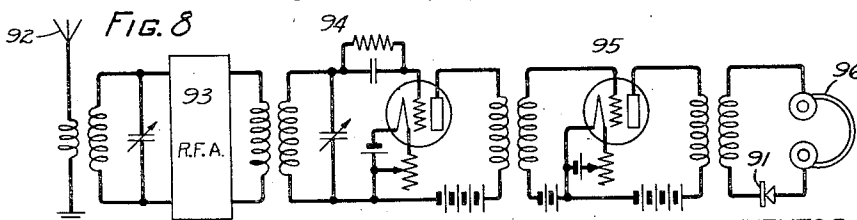
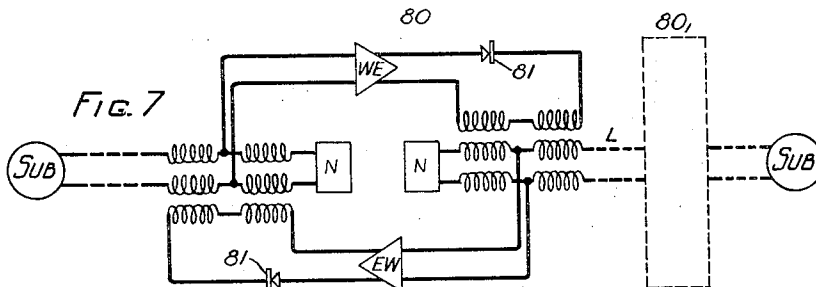
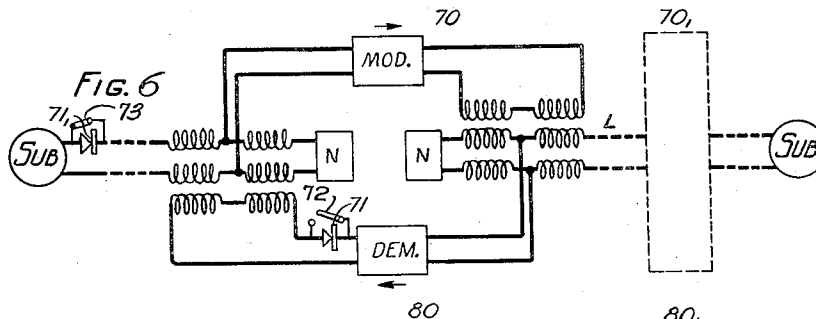
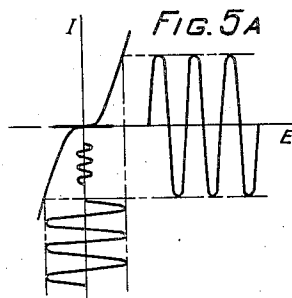
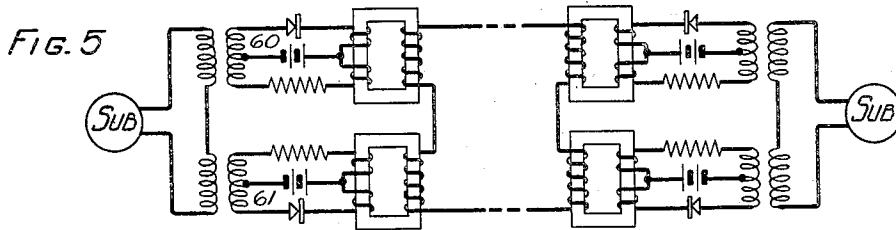
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APPARATUS FOR REDUCING CROSSTALK CURRENTS

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3 Sheets-Sheet 2



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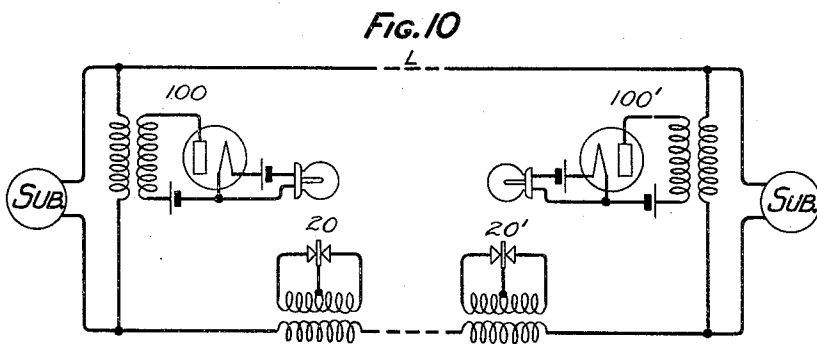
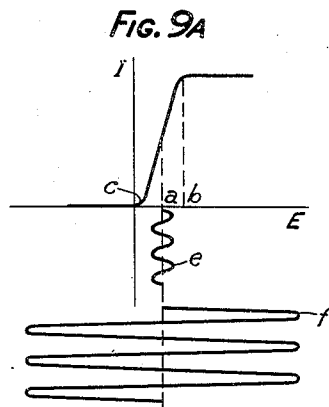
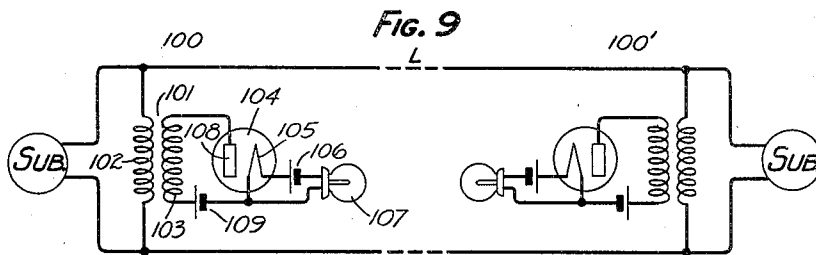
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APPARATUS FOR REDUCING CROSSTALK CURRENTS

Filed June 20, 1928

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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APPARATUS FOR REDUCING CROSSTALK CURRENTS

Application filed June 20, 1928. Serial No. 286,773.

This invention relates broadly to methods and apparatus for discriminating between currents of different amplitudes and in particular to systems which may be used to eliminate noise or crosstalk from signaling circuits.

Noise or crosstalk is mostly objectionable during pauses in conversation so that it is desirable to have some means which will effectively prevent transmission of crosstalk currents but which at the same time will have negligible effect upon the transmission of speech currents. Since the amplitudes of the crosstalk currents are small in comparison with the amplitudes of speech currents, a device which discriminates between the two, and permits only speech current to pass to the signal detecting device is suitable for this purpose.

An object of the invention is to reduce the effect of disturbing currents in a signaling system during the intervals between signal impulses.

A related object of the invention is to eliminate noise or crosstalk from telephone circuits during pauses in conversation. In one aspect of the invention the object is accomplished by the use of crystals or other elements which offer a different impedance to currents in one direction than in another.

In one form of the invention an element having a non-linear current voltage characteristic is placed in a voice frequency line. Such an element may be similar to the ordinary rectifier having a high resistance when current is in the negative direction and a low resistance when in the positive direction. Ordinarily in this type of element the change of the current voltage characteristic from the region of high to low impedance is not abrupt, but rather an even curve although the change takes place within a comparatively small voltage range. Thus, when a single element is used, currents of small amplitudes will be entirely suppressed whereas the positive lobes of large currents will be transmitted. If two of these elements be used together oppositely poled the transmission circuit has a characteristic showing a region of non-transmission for currents of small amplitudes,

such as crosstalk, whereas both the positive and negative lobes of the currents of larger amplitude or voice currents are readily transmitted.

In some cases it has been found that a single crystal, such as carborundum may be used to reduce the transmission of small currents without affecting the transmission of speech currents when it is connected in the circuit between two plates having large surfaces of contact with the crystal.

In another embodiment of the invention a crystal is used in conjunction with an ordinary resistance element. Here again the crystal element has a non-linear current voltage characteristic having a high resistance when the current is negative and a low resistance when positive. The resistance element has a value which is approximately equal to that of the crystal when the current is in the negative direction. The resistance and the rectifying elements are connected in the line such that the current transmitted thereover will pass through the resistance and rectifying element in opposite directions. When the current is in the direction to which the resistance offered by the rectifier element and the fixed resistance are equal, which as stated above, will result when the current is negative, the resultant current will be zero, whereas for positive currents, a resultant current will flow due to the resistances being unbalanced.

Thus, the current voltage characteristic of this device shows a region of non-transmission for negative voltages, whereas for positive voltages the current varies directly with the voltage.

However, as in the case of a single crystal the transition from one portion of the curve to the other does not take place abruptly and as in the former case for small positive voltages, substantially no current flows thus discriminating against currents of small amplitudes.

By the use of two such arrangements oppositely poled with respect to each other the characteristic of the resultant circuit is such that small positive and negative voltages transmit no current whereas normal voltages such as those due to speech signals are trans-

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mitted substantially without distortion. In all these cases by properly biasing the rectifying elements in a manner well known in itself the region over which the applied voltage operates to transmit no current may be regulated.

In another embodiment of the invention a similar result is accomplished by using a device in shunt with the signal receiving means. This device readily transmits current of small amplitudes and offers a path of high resistance to current of large amplitudes corresponding to the speech current. With this arrangement the small or disturbing currents are shunted around the receiving means whereas the speech currents find a path of less resistance through the receiver. Greater discrimination is secured if both the series and shunt type discriminators are simultaneously used in the circuit.

A further understanding of the invention may be had from the following description when read in connection with the accompanying drawings of which:

Figs. 1 and 1—A represent, respectively, a simple schematic of a subscriber's telephone circuit to which the invention in one of its simplest forms is applied, and the transmission characteristic of the circuit;

Figs. 2 and 2—A show another subscriber's circuit embodying the invention and the transmission characteristic thereof;

Fig. 3 shows the invention as applied to a balanced telephone line;

Fig. 4 shows an embodiment of the invention in which a current through a resistance is balanced against the current through a rectifier, while Fig. 4—A illustrates the transmission characteristic of such a circuit;

Figs. 5 and 5—A illustrate a circuit and its transmission characteristic in which the embodiment, as disclosed in Fig. 4, is shown applied to a subscriber's circuit for transmitting both half cycles of the signal wave.

Figs. 6, 7 and 8 show several applications of the invention to telephone systems and radio receiving systems.

Fig. 9 illustrates the shunt type of discriminator applied to a subscriber's telephone circuit and Fig. 9—A its transmission characteristic.

Fig. 10 shows an arrangement in which both shunt and series discriminators are simultaneously used.

Referring now to Fig. 1, the current amplitude discriminator 10 is shown in one of its simplest forms applied to a subscriber's telephone circuit in which the subsets are of any well-known type at the respective terminals of the line L. A transformer 1 preferably of high impedance ratio has its primary winding 2 connected in one side of the line, while in series with its secondary winding 3, an element 4 having a non-linear impedance characteristic of any well-known type, such

as a copper oxide crystal, carborundum crystal, space discharge rectifier or the like may be used. A current amplitude discriminating device 10, similar in all respects to element 10 is placed at the other end of the line in similar association with the other subscriber's set.

The operation of the circuit may best be understood by reference to the transmission characteristic curve *d* as shown in Fig. 1—A. This curve (as do all the other curves showing current transmission characteristics), shows the variation of current with voltage, the ordinate representing current and the abscissa voltage. Below the characteristic curve is plotted the alternating voltage wave generated in the line while at the right is the resulting current wave. This characteristic curve is typical of the transmission element which is preferably used in carrying out the invention. It will be noticed that for very small positive voltages as well as negative voltages applied to such an element, the resistance offered to the resultant current is large, whereas for large positive voltages the resistance offered to the current is comparatively small.

Thus, when a small voltage as represented by *a* in Fig. 1—A is generated in the line L, due to noise or crosstalk, the high resistance offered limits the current flow to a value so small that no attempt has been made to show it on the drawings. However, when large voltages, represented by the wave *b* corresponding to those generated by normal speech are present, the resistance offered is comparatively small, resulting in the transmission of a current of considerable amplitude as shown by the wave *c*.

Although the discriminating element 4 might be used if merely inserted in series in the line, more effective discrimination is possible when a transformer is used. Such a transformer is preferably of the step-up type with the low winding 2 in the line. As can be seen from the characteristic curve of 1—A the voltage across the transmission element 4 necessary to reduce its resistance to permit the flow of speech current is comparatively high. In some instances the voltage necessary to operate the element at a point to permit sufficient current to flow is larger than that available in the line. By using a step-up transformer of the proper ratio, the voltage across the element 4 when signals are being transmitted in the line, is made large enough to reduce the impedance of the element to such a value that the requisite current is permitted to flow.

When small voltages, due to disturbing currents or crosstalk, are generated in the line, the impedance of the discriminating element 4 being high, the largest voltage drop in the circuit is across the primary of the transformer 2 or the corresponding winding

of the discriminating circuit 10. The voltage drop through the subscriber's set will therefore be correspondingly small and of little effect. However, during signaling periods, the transformer increases the voltage across the element 4 to a point where the value of impedance in the secondary circuit is comparatively small. If perfect coupling is assumed the impedance across the winding 2 is less than that of the secondary circuit and is equivalent to that of the secondary circuit multiplied by a factor equal to the reciprocal of the square of the transformer ratio. The voltage drop across the winding 2 during signaling is small in comparison to the drop in the rest of the circuit and occasions small loss.

In Fig. 2 another embodiment of the invention is shown. In this instance, a balanced discriminator comprises transmission elements 14 and 15 which are connected in series opposed relation with each other. The rectifiers have like electrodes connected to the opposite ends of the secondary winding 13 of transformer 11 and a common connection 16 from the other like electrodes to the middle of the winding 13. The other end of the line is similar in all respects.

By reference to Fig. 2—A which shows the current voltage transmission characteristic of this circuit, it is apparent that more symmetry is gained for positive and negative voltages than is possible in a circuit having the characteristic of Fig. 1. This transmission characteristic shows a region of non-transmission for small positive and negative voltages. A wave of small amplitude corresponding to crosstalk is shown at *e*, the current resulting therefrom being effectively zero, whereas the currents for normal speech voltages as shown at *g* result from a voltage of the magnitude *f*. Thus, there is very small attenuation of a voice current. With the symmetrical characteristic provided by the balanced arrangement, the resistance offered to both positive and negative voltages is the same, thereby reducing distortion to a considerable extent. The even order harmonic products which may be introduced by the transmission elements are also substantially suppressed with the balanced arrangement.

A carborundum crystal having two electrodes electro-plated on opposite faces to insure a large surface of contact gives a non-linear current voltage characteristic curve which is symmetrical about zero like that shown in Fig. 2—A when connected in the circuit as element 4 in Fig. 1.

Fig. 3 shows the invention applied to a balanced subscriber's line. In this embodiment the transformer 21 is a three-winding transformer having windings 22 and 24 in each side of the subscriber's line *L* to maintain the line in proper balance. The third

winding 23 with which the rectifiers 25 and 26 are associated has the same coupling with the winding 22 as with winding 24. In all other respects, this circuit is the same as that shown in Fig. 2, the operation and transmission characteristic being the same.

In Fig. 4 the subscriber's set is coupled to the current amplitude discriminator through a repeating coil 31 having windings 32 and 33. One end of winding 33 is connected to the winding 39 of the transformer 37 through the rectifier element 34, while the other end of winding 33 is connected to the winding 38 of transformer 37, through the resistance 35, the magnitude of which is chosen in accordance with the considerations which will be subsequently discussed. The mid-point of winding 33 is connected to the other ends of windings 38 and 39 through a source of biasing potential 36. The windings 38 and 39 are oppositely poled.

The operation of this circuit will be described with reference to Fig. 4—A. The element 34 has a non-linear impedance which is much greater when current is flowing in the negative direction. The transmission characteristic of this element is shown by the dotted line *h* in Fig. 4—A. The resistance 35 is proportioned so as to be equal to the resistance offered by the transmission element 34 to negative current.

When speech current is flowing in the transformer winding 32, voltage is induced in the winding 33 and produces current flow in the same direction in both the upper circuit comprising the element 34, the upper half of winding 33, the source of biasing potential 36 and the winding 39 and also in the lower circuit comprising the resistance 35, the winding 38, the source of biasing potential 36 and the lower half of winding 33. By virtue of windings 38 and 39 being oppositely poled, the current which is transmitted to the line *L* is the resultant of the currents flowing in windings 38 and 39. Referring to Fig. 4—A, the dot and dash line *i* is the current voltage characteristic of the resistance 35. This, of course, is linear. The solid line *k* represents the resultant current voltage characteristic of the circuit, from which it may be readily seen that when a negative voltage is impressed upon the circuit, no current is transmitted, whereas positive voltages of signal magnitude cause a resultant current to be transmitted which is of substantial value. The horizontal region of the resultant transmission characteristic curve may be made to extend to the right or positive side of the point of zero potential by regulating the value of the biasing source of potential 36. As shown in Fig. 4—A, a sufficient biasing potential has been used so as to completely prevent the transmission of small potentials, such as those which correspond to noise or crosstalk, whereas no appreciable suppression results to the

positive half cycles of normal signaling waves.

Fig. 5 shows a circuit utilizing two units 60 and 61 in all respects similar to that shown in Fig. 4 at one end of the subscriber's line. In order to obtain a transmission characteristic which is substantially symmetrical about the point of zero potential, the units are poled opposite to each other so that one operates to transmit current when the voltage is in the positive direction, while the other transmits current when the voltage is in the negative direction. With this arrangement, the resistances in the circuit are equal for voltages of the same absolute value regardless of their polarity, and the resultant current transmitted is proportional thereto and substantially distortionless.

Fig. 5—A shows the transmission characteristic of such a circuit with its small region of non-transmission to the right and left of the value of zero potential for suppressing voltages of small magnitude. Here also the extent of this region may be varied by properly regulating the biasing voltages.

Although all of the embodiments of this invention thus far mentioned have been described in connection with the transmission of speech in one direction, it is to be understood that all the circuits are adaptable to two-way transmission. Furthermore, all the transformers may be the high impedance type as described in connection with Fig. 1.

Fig. 6 shows the invention applied to a carrier system. Terminal apparatus 70 includes a modulator and demodulator of a carrier system, such as that described in a paper presented by E. H. Colpitts and O. B. Blackwell entitled "Carrier current telephony and telegraphy" published in the proceedings of the A. I. E. E. of April, 1921. The line L is terminated at the other end by similar apparatus 70₁. The amplitude discriminator 71 may be any one of the types heretofore described and is shown located on the voice frequency side of the demodulator since in this position it possesses the greatest efficacy for suppressing the undesired currents. This position is preferred to the one on the carrier line side of the modulator since in the latter position, the variable impedance of the discriminator is liable to affect the impedance of the line to an undesired extent. The discriminator may also be located in the alternate position 71₁ by closing switch 72 and opening switch 73.

In Fig. 7 a voice frequency repeater 80 is shown which may be of any well-known type, as for instance, similar to that described in the article "Telephone repeaters" by Gherardi and Jewett, published in the proceedings of the A. I. E. E. of November, 1919. The crosstalk discriminators 81, which may be of any of the types heretofore described, are shown in the output circuits of

amplifiers WE and EW. Since this is the position of greatest amplification, the range of potential over which it is desirable that the discriminator operate is more readily regulated. Furthermore, in this position any distortion which the discriminator may tend to produce is not amplified into the line.

Fig. 8 shows the discriminator as applied to a radio receiving circuit which may be of any type known to the art. The particular one shown has provision for radio frequency amplification at 93, coupling the antenna 92 with the detector stage 94. The detector circuit feeds into an amplifier for audio frequency 95 which, in turn, is coupled to a circuit comprising the receiving instrument 96 and the discriminating device 91. The receiving instrument may be of any well-known type and the discriminating element may be of any of the types herein described. The discriminator serves to reduce disturbing currents in the receiver during intervals between signaling such as may be caused by atmospherics instant upon the antenna, variations in battery supply, stray electric fields in close proximity to the receiver or from any other source.

In the circuits thus far described the discriminating elements have been all of the series type. Similarly effective results may be obtained by using a shunt type element. Such an arrangement is shown in Fig. 9. Herein discriminating elements 100 and 100', identical in all respects, are associated with the respective subscribers' units located at opposite ends of the transmission line L. Winding 102 of transformer 101 is connected in shunt to the line L while the other winding 103 has its opposite ends connected to different electrodes of a two-element space discharge tube 104. The filament 105 of the space discharge tube is energized from a source of energy 106, and its filament emission is maintained constant by a ballast lamp 107. The plate 108 of the tube is positively biased by a source of potential 109. The transmission characteristic curve of the space discharge device 104 is shown in Fig. 9—A. The source of biasing potential 109 has a value which permits the space discharge device to operate symmetrically about that point on its characteristic which is midway between its point of saturation and the point where plate current begins to flow. In the figure the mid-point is designated by *a* and the other two points are designated by *b* and *c* respectively.

The plate potential and filament emission are such that the region between the points *c* and *b* extends over a sufficient range of voltages to readily transmit the small or crosstalk voltage waves. These voltages are represented by the wave *e*. When a large voltage wave of speech magnitude is generated in the line the tube 104 blocks for one

half of the wave and operates above the point of saturation for the other half so that practically no current is transmitted. Since the shunt path has low resistance for currents of small amplitudes during pauses in conversation the disturbing currents are shunted around the receiver. However as the shunt path offers high resistance to currents of large amplitudes such as speech signals practically all the speech passes through the receiver or utilization circuit.

Fig. 10 illustrates a circuit in which more effective discrimination is obtained by using both a shunt type discriminator 100 and a series type discriminator 20 similar to those correspondingly designated in the figures previously described.

Although the shunt type discriminator has been described with reference to a simple subscriber's line, it is to be understood that it may also be used in any of the circuits to which the series type heretofore described may be adapted.

The application of Victor E. Legg, Serial No. 362,903, filed May 14, 1929, for noise suppressing circuit, claims a crosstalk suppressor circuit for a telephone line comprising rectifying crystal elements connected to provide paths of free transmission for normal speech currents in both directions over the telephone line but only paths of high impedance to currents of crosstalk level. The present invention is an improvement over that invention.

It will be apparent that the various circuits which have been described herein are only typical embodiments of the broad idea and that various other embodiments will at once be suggested to those skilled in the art. The invention, therefore, is to be limited only by the scope of the appended claims.

What is claimed is:

1. The combination with a circuit for the transmission of signal waves of mechanically static transmission means associated with said circuit having the property of bilaterally freely transmitting said signal waves practically undistorted while suppressing the transmission of disturbing currents having amplitudes small in comparison with said signal waves, and means for determining the range within which said disturbing currents are suppressed.

2. The combination with a circuit for the transmission of signal waves of a transmission element associated with said circuit having the property of bilaterally freely transmitting said signal waves practically undistorted while suppressing the transmission of disturbing currents having amplitudes small in comparison with said signal waves and a source of biasing potential for said transmission element for determining the point at which discrimination occurs.

3. The combination with a circuit for the

bilateral transmission of signal waves of an amplitude discriminating means for transmitting signals in both directions in said circuit, said means comprising a plurality of transmission elements each having the property of readily transmitting signal waves of one sign only, but of substantially suppressing distorting currents having amplitudes small in comparison with said signal waves, said plurality of transmission elements being associated together in such a manner that their resultant transmission characteristic, for signal waves propagated in both directions through said circuit and said means, is substantially symmetrical about the point of zero potential and has a region of non-transmission for said disturbing currents.

4. The combination with a circuit for the bilateral transmission of signal waves of a plurality of transmission elements each having the property of freely transmitting normal signal waves of but one polarity and of readily suppressing small voltages corresponding to crosstalk, said elements being arranged in balanced relation with respect to each other, and related to said circuit for bilateral transmission of signals propagated in both directions through said circuit and said means, and means for supplying biasing potential to said elements, said elements being capable of suppressing the transmission of current over a range determined by said biasing potential but of transmitting normal signal waves substantially without distortion.

5. In a circuit for the transmission of signal waves to a utilization circuit for employing waves within the frequency range of the waves transmitted over said transmission circuit, the combination therewith of means comprising a crystal for differentiating between currents of small amplitudes corresponding to crosstalk and large amplitudes corresponding to normal signal waves, said means comprising auxiliary means for predetermining the energy level below which crosstalk currents are substantially prevented from being transmitted to said utilization circuit.

6. A current discriminating circuit comprising an element offering different impedances to currents in opposite directions, and another impedance associated therewith for reducing the transmission efficiency of said circuit substantially to zero for impressed waves of small amplitude of one sign and for impressed waves of the opposite sign when they are of small amplitude but not when they are of a given range of greater amplitudes.

7. A current amplitude discriminating device comprising an element having different finite impedances for currents of opposite signs, another impedance associated therewith having for currents of each sign a value equal to the greater impedance of said

first element, and means for impressing a voltage upon said elements to cause the currents therethrough to oppose each other.

8. The method which comprises producing from two original waves two resulting waves having an amplitude ratio greater than that of the original waves, deriving from the original waves two waves having an amplitude ratio that differs from that of the original waves less than does the first mentioned ratio, and balancing said derived waves against said resulting waves.

9. In combination, means for transmitting two waves differing in amplitude with higher efficiency for the wave of higher amplitude than for the wave of lower amplitude, to produce two resulting waves, means for transmitting the original waves with equal efficiency of such degree as to produce two other waves one of which is equal in amplitude to one of said resulting waves, and means for balancing said other waves against said resulting waves.

10. A signaling circuit comprising two transmission elements having different types of transmission characteristics, means responsive to signaling voltages and to small disturbing voltages in said circuit for causing currents through said elements, and means for combining effects of currents through one of said elements with effects of currents through the other element to produce resultant effects, one of said elements having its transmission characteristic so related to that of said other element that the resultant effect of those of said first mentioned currents that result from said small disturbing voltages, but not the resultant effect of those of said first mentioned currents that result from said signaling voltages, is substantially smaller than either of the effects which produce the resultant effect.

11. In combination, two transmission elements, the transmission characteristic of one changing its slope relative to the transmission characteristic of the other at a small positive value of applied voltage, means for applying alternating voltages to said elements, and means for causing the resulting output of one to oppose and thereby reduce an effect of the resulting output of the other.

12. In combination, two transmission elements, the impedance of one being constant whereas the impedance of the other is constant for applied voltages of negative values and of small positive values but changes at a small positive value of applied voltage, means for causing currents through said elements, and means for causing the current through one of said elements to substantially neutralize an effect of the current through the other element.

13. In combination, two transmission elements, the impedance of one being constant and the impedance of the other being con-

stant for applied voltages of negative values and of small positive values but changing at a small positive value of applied voltage, means for causing alternating currents through said elements, and means for causing small alternating currents through one of said elements to substantially neutralize the effect of small alternating currents through the other element.

14. The combination with a circuit for the transmission of waves and a utilization circuit associated therewith employing waves within the frequency range of the waves transmitted over said transmission circuit, of transmission means associated with said transmission circuit for discriminating against transmission of waves of small amplitude and in favor of waves of greater amplitude to said utilization circuit, said means being at all times in condition to transmit said latter waves to said utilization circuit, and means for normally biasing said transmission means to an operating point on its transmission characteristic corresponding to an applied voltage lower than the applied voltage that corresponds to zero current from said transmission means.

15. The combination with a circuit for the transmission of waves and a utilization circuit associated therewith employing waves within the frequency range of the waves transmitted over said transmission circuit, of transmission means associated with said transmission circuit for discriminating against transmission of waves of small amplitude and in favor of waves of greater amplitude to said utilization circuit, said means being at all times in condition to transmit said latter waves to said utilization circuit, and means for cooperating with said transmission means to effect complete suppression of transmission of said waves of small amplitude to said utilization circuit.

In witness whereof, I hereunto subscribe my name this 11th day of June, 1928.

EUGENE PETERSON.